CULTURE AND USE OF GRAIN SORGHUM

Agriculture Handbook No. 385

Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE

PRECAUTIONS

Pesticides used improperly can be injurious to man, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers under lock and key —out of the reach of children and animals—and away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides when there is danger of drift, when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment if specified on the container.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Do not clean spray equipment or dump excess spray material near ponds, streams, or wells. Because it is difficult to remove all traces of herbicides from equipment, do not use the same equipment for insecticides or fungicides that you use for herbicides.

Dispose of empty pesticide containers promptly. Have them buried at a sanitary land-fill dump, or crush and bury them in a level, isolated place.

NOTE: Some States have restrictions on the use of certain pesticides. Check your State and local regulations. Also, because registrations of pesticides are under constant review by the U.S. Department of Agriculture, consult your county agricultural agent or State Extension specialist to be sure the intended use is still registered.

PROTECT

Use Pesticides Safely
FOLLOW THE LABEL
U.S. DEPARTMENT OF AGRICULTURE

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CULTURE AND USE OF GRAIN SORGHUM

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Grain sorghum is a member of the grass family and is closely related to forage sorghum (sorgo), broomcorn, sudangrass, johnsongrass, and sorghum almum. It includes basic groups recognized in the United States as milo, kafir, durra, hegari, feterita, shallu, and kaoliang; pure-line varieties derived by hybridization and selection; and F_1 hybrids. For many years most of the grain sorghums in the United States were either milo or kafir. Consequently, "milo" is still popularly, though not accurately, used for all grain sorghums, including F_1 hybrids. "Milo maize," "kafir corn," and "maize" applied to sorghum are misnomers.

A sorghum called chicken corn was introduced on the southern Atlantic coast in colonial times, but the culture did not persist and the variety escaped as a weed. A non-noxious type called Guinea corn was introduced during the same period and was c[illegible]d until the 20th century before disappearing. The crop as we know it became established in the late 19th and early 20th century. Practically all grain sorghums of economic importance, until recent years, were introduced between 1874 and 1908 and have been the base for varietal improvement.

Today grain sorghum is a major crop of the Great Plains and the Southwest. It is grown both as a dryland and as an irrigated crop. Texas, Kansas, and Nebraska account for over 80 percent of the Nation's production (table 1). Most of the remaining production is in Arizona, California, Colorado, Missouri, New Mexico, Oklahoma, and South Dakota. The Corn Belt and the South produce from 1 to 2 percent of the total.

Production in the United States by 5-year periods for 1919–68 is shown in table 2. Except for the drought of the 1930's, yield per acre and total production have trended upward with a spectacular rise during 1958–68. Record grain production was achieved in 1967 at 756 million bushels. The highest yield per acre was in 1966 at 56 bushels or 3,100 pounds.

= 55 lb/bu.

[1] The authors have revised and expanded the information in AIB 218, "Culture and Utilization of Grain Sorghum," for this handbook.

TABLE 1.—*Sorghum grain production in major States, 1968* [1]

State	Acres	Yield per acre [2]	Total production [3]
	Thousands	*Bushels*	*1,000 bushels*
Texas	6,196	55.0	340,780
Kansas	3,475	47.0	163,325
Nebraska	1,776	58.0	103,008
Oklahoma	638	41.0	26,158
California	360	70.0	25,200
Arizona	231	79.0	18,249
New Mexico	279	56.0	15,624
Missouri	216	66.0	14,256
Colorado	290	35.5	10,295
South Dakota	244	34.0	8,296
Total or average (10 States)	13,705	53.0	725,191
Total or average (U.S.)	13,971	53.0	738,507

[1] U.S. Dept. Agr. Crop Rptg. Bd. report; includes sweet sorghum for seed.
[2] No. 2 grain sorghum usually computed at 56 pounds per bushel.
[3] Does not always equal acres × yield because of figure rounding.

TABLE 2.—*Sorghum grain production in United States, 1919–68* [1]

Years	Acres	Yield per acre	Total production [2]	Predominant type grown
	Thousands	*Bushels*	*1,000 bushels*	
1919–23	3,786	18.2	68,761	Tall variety.
1924–28	4,004	17.3	69,390	Do.
1929–33	4,047	13.8	55,985	Do.
1934–38	3,880	12.6	48,849	Do.
1939–43	6,006	15.7	94,367	Transition.
1944–48	7,035	17.4	122,333	Combine variety.
1949–53	7,426	20.2	150,270	Do.
1954–58	14,005	26.2	366,322	Transition.
1959–63	13,378	41.1	550,250	Hybrid.
1964–68	13,311	50.7	674,386	Do.

[1] U.S. Dept. Agr. Agr. Statis. and U.S. Dept. Agr. Crop Rptg. Bd. reports; includes sweet sorghum for seed.
[2] Does not always equal acres × yield because of figure rounding.

GENERAL ADAPTATION

Grain sorghum is grown chiefly in the Great Plains, where most of the rainfall occurs during the growing season. The crop is planted at the beginning of the wet period and harvested at the beginning of the dry period. Warm, dry autumns normally reduce moisture in the grain so that it retains a bright color.

Wet periods following maturation of grain cause its discoloration and encourage fungus growth. High-moisture grain also introduces a storage problem. Generally these hazards are more common to the eastern edge of the sorghum-growing area and to the Corn Belt, where artificial grain driers are used, but they can occur in the driest areas of the Great Plains in some years.

The superiority of grain sorghum over other crops lies in its ability to produce grain with a relatively limited supply of water. The crop is unique in that it can remain dormant during stress periods and renew growth when conditions are more favorable. Grain sorghum is not immune to heat and drought, and prolonged periods of such weather may prevent plant and grain development to the extent that a crop cannot mature before frost or yield is reduced. On the other hand, grain sorghum responds as well as or better than most crops to conditions of favorable rainfall or irrigation. Yields of 8,000 pounds or more per acre frequently are obtained with adequate moisture and high fertility. The crop also is more tolerant of flooding than corn, but it does not grow best under prolonged wet conditions.

Maturity is an important consideration. The first varieties grown were late maturing and best adapted to Texas and Oklahoma. Improved selections of earlier maturity enlarged the main sorghum-growing area to Kansas and Nebraska, and finally varieties were bred for the short-growing seasons of the western high plains and the north-central plains. However, cool soil temperatures of the northern latitudes and at higher altitudes following planting can delay seedling growth, and cool nights can delay later growth and grain maturity of the best adapted types. They are deterrents to consistent maximum production.

On the other hand, grain sorghum generally withstands the high temperatures of the Southwest provided soil moisture is adequate, although it is desirable not to have the crop flower and set seed during the hottest part of the summer. Because of the long growing season, varieties can be chosen and planting dates altered so that blooming follows the usual adverse period.

Grain sorghum grows successfully on all soils though it does best on medium-textured types. It grows slightly better on sandy or light-textured soils than it does on clayey or heavy-textured soils. The latter can produce high yields if moisture is ample, but the crop will exhibit drought symptoms during dry periods. Usually the heaviest soils are better adapted to wheat in the Great Plains. Tillering of grain sorghum tends to decrease as the percentage of silt and sand soil fractions increase. The sorghum plant also tolerates medium high pH's as evidenced by the alkaline condition of many soils in the growing region.

In addition to weeds, insects, and diseases, birds are a serious pest of grain sorghum. Sparrows and blackbirds are the most destructive species in the United States, though others sometimes attack the crop. Destruction is most prevalent in fields that border farmsteads, wooded streams, and windbreaks. Damage to the head begins at the milk stage and lessens as the grain ripens. A few varieties like Darset and Combine Sagrain, certain brown-seeded hybrids like AKS 614, GA 609, GA 615, and RS 617, and some commercial hybrids are distasteful to birds. These types are more likely to be grown in the problem areas of Arkansas, eastern Oklahoma, and the Southeast than in the Great Plains or Southwest.

VARIETIES AND HYBRIDS

Most of the first improved varieties came from selections in milo and kafir and a few from other basic types. Pure-line varieties were developed later through hybridization and selection. All were tall growing, some had recurved heads, and none were adapted to machine harvest. Some of these varieties like Pink kafir, Blackhull kafir, and Dwarf Yellow milo firmly established grain sorghum culture in the United States. These sorghums were more dependable than corn in the areas where grown and were nutritious for livestock feed.

Combine-height grain sorghum that could be harvested with a wheat header was developed before World War I by a farmer-plant breeder, H. Willis Smith, of Garden City, Kans. But his efforts were premature, and the types were not accepted by either the farmers or the agriculturalists of the day. Beaver, a short-statured variety with an upright head suitable for combine harvest, was released by the Oklahoma Agricultural Experiment Station in 1928. It was grown on a limited acreage but was soon replaced by the superior Wheatland variety, which gained wide popularity. The latter marks the beginning of the combine-sorghum era and a significant step in grain sorghum improvement.

Acceptance of combine grain sorghum was not immediate but was stimulated by the drought of the 1930's and fostered by the release in the early 1940's of stiff-stalked types like Martin, Westland, Plainsman, Caprock, and Midland. A farm manpower shortage during World War II also prompted their adoption. These five varieties, along with subsequent developments—Combine 7078, Combine Kafir-60, Dwarf Kafir 44–14, Early Hegari, Norghum, Redbine-60, Redbine-66, Redlan, and Reliance—constituted most of the acreage when hybrids were introduced in the mid-1950's.

Hybrid grain sorghum is based on a male sterility-fertility restoration technique. A method for making hybrids on a large scale, as by detasseling in corn, is impossible in sorghum because male and female flowers are located together on the plant. The first hybrid seed was a three-way genetic male-sterile cross, but it was soon discarded in favor of a more manageable single-cross system based on cytoplasmic male sterility. Hybrid seed was available in quantity for farm planting in 1957, and the amount of the crop planted to hybrids rose rapidly to nearly 100 percent in the following decade. Along with favorable growing seasons and improved cultural methods, particularly increased fertilizer usage and more irrigation, hybrids help account for the remarkable yield and production increases of recent years.

Grain sorghum hybrids are commonly designated by number. State and Federal agencies have adopted a uniform system of nomenclature for experiment station hybrids. The hybrids are assigned numbers based on maturity classes in relation to standard varieties as follows:

Maturity class	*Series*
Earlier than Norghum	300
Norghum	400
Reliance	500
Martin	600
Plainsman	700
Dwarf Kafir 44–14	800

Most of the hybrids in the major grain sorghum area are in the 500 to 700 range, with the 600 series most common.

Hybrids developed by public agencies may have a State prefix, e.g., OK (Oklahoma) and NB (Nebraska), indicating that recommendation and interest were limited to one State at the time of release. Or they may have an RS (Regional Sorghum) prefix, indicating wider interest and wider initial distribution. Though some commercial companies number hybrids according to maturity, a few name them as was the custom with varieties.

SEED SELECTION AND TREATMENT

Plant only high-quality seed. The cost is minor considering the low amount sown per acre. High quality in grain sorghum refers to trueness to type, high and strong germination, and freedom from weed seeds, inert matter, and other crops. These last three can often be removed through cleaning, since sorghum seed is relatively large compared to seed of many farm crops like grasses and legumes. High germination results from harvesting mature seed without freeze or mechanical damage and storing it under proper conditions of temperature and humidity. Artificial drying of seed is sometimes used advantageously, but the temperature must be controlled to maintain germination. Laboratory germination tests eliminate most poor seed lots before fields are planted.

Clean seed of high germination that appears uniform can produce offtype plants in the field. They arise from two causes—plant mutations during the growing season and outcrosses occurring in the production field the previous season. These offtypes are genetic and are in addition to those coming from mechanical seed mixtures or from volunteer seeding.

Mutation to a taller height occurs naturally at a low regular frequency in most combine grain sorghum varieties and hybrids. Mutants appear to be worse in high than in low plant populations. Their presence is an accepted fact of grain sorghum culture. The mutants are similar to the rest of the population but are a head or more taller. The cause is an unstable genetic height factor.

Outcrosses in sorghum take place because the crop is not completely self-pollinated. In hybrids they can be potentially high, since a large proportion of the production field has male-sterile seed rows. Under ideal conditions an abundance of pollen from the male rows will pollinate the sterile plants as the flowers become receptive. Under less ideal conditions airborne foreign pollen will pollinate the sterile plants.

The most serious pollen contaminants are forage sorghum, sudangrass, sorghum-sudangrass hybrids, wild cane (shattercane), johnsongrass, and sorghum almum. They produce outcrosses in grain sorghum that are tall and break over at combining, or they shatter their seed before maturity. They have created sorghum weed problems through propagation of undesirable progeny. Outcrosses from other grain sorghum in small amounts are usually not of economic importance and are seldom noticed when the same seed colors and same height factors are involved.

Reputable commercial seedsmen and producers under State certification programs follow stringent standards to assure the production of high-quality seed. They plant on clean ground, isolate hybrid crossing fields from other sorghum fields, regularly rogue offtypes from the field, and exercise good practices of harvest, processing, and storage of the seed crop. In addition to laboratory tests, they commonly make field tests of seed lots in the Tropics during the winter to detect those that are substandard.

Seed of hybrid grain sorghum must be purchased new each year; otherwise genetic segregation into many types and also yield reduction will occur. Most farmers are acquainted with this from knowledge of hybrid corn.

Many grain sorghum hybrids are available to the farmer, and most of them are marketed by commercial seed companies. A decision for planting a hybrid should be based on its performance over several years, since erratic weather patterns can greatly alter year-to-year performance. Data are available from tests conducted by companies and agricultural experiment stations.

County agents have published results of the latter.

Prior to the general use of hybrids, grain sorghum was treated with a fungicide on the farm at the time of planting, if treated at all. Little or none was treated with an insecticide. A fungicide treatment is desirable to ward off soilborne organisms that cause seed decay or attack the young seedlings. Stands are improved and greater seedling vigor may be reflected in higher yields at harvest. Fungicides will control kernel smuts of sorghum but not head smut.

Most hybrid seed is treated with a fungicide-insecticide combination before packaging or distribution to the dealer. The insecticide protects against insects that attack the seed in the soil such as wireworms and kafir ants. Captan and thiram are the most common fungicides and malathion, methoxychlor, and other insecticides are used.

SEEDBED PREPARATION

A well-prepared seedbed is essential for full stands and for weed control. Tilling fields usually improves soil structure and often aids in warming the ground. In dry areas of the Great Plains, proper seedbed preparation helps conserve soil moisture.

In the Corn Belt and the South, the seedbed for grain sorghum is prepared similarly to that for corn and cotton. The soil is turned with a moldboard plow and later tilled by disking and harrowing.

In the central and northern Great Plains, grain sorghum is planted on fallow or it follows wheat or sorghum. Tillage practices are the same in either rotation except fallow ground has an intermediate period of summer cultivation. The moldboard plow is almost always used for seedbed preparation on irrigated land. Stubble fields commonly are undercut or one-way diskplowed after small-grain harvest if grain sorghum is to be planted the following year. The stubble is left standing by blading and holds blowing snow, which increases the stored winter moisture. Blade-type tools are operated at a depth of 5 to 7 inches for primary tillage, such as after wheat harvest, and less deep for secondary tillage. One-way disk plows do not cut so deep and function best in years of abundant rainfall when plant growth is heavy and recurring. In dry years they tend to destroy the vegetation and pulverize the soil. Formerly much land was chiseled in preparation for planting grain sorghum. Chisels break up the soil to a depth of 8 to 12 inches or more, and are used when wind erosion is troublesome during the winter and early spring. Also, the lister was more popular in former times, though a modification of it, the bedder, is popular in irrigated areas.

In the southern Great Plains, much grain sorghum is grown by continuous cropping. Fallowing is not practiced in most of this region because moisture evaporation is high and many soils are sandy and have a low water-retention capacity. In the Southwest, grain sorghum usually is grown in rotation with cotton.

In the spring the soil may need tilling once to several times before planting grain sorghum. Frequent tillage is necessary when the spring is wet and weed growth is rapid. The destruction of weeds is important to avoid competition with the crop. Grain sorghum seeds often germinate rather slowly, and the seedlings are too small to compete successfully with weeds until about 4 weeks after planting. Soil-moisture loss by surface drying may be high during dry spring weather, but usually fewer weeds grow then. In much of the Great Plains, land is tilled in the spring with a high probability of getting rain near planting time. It is not advisable to plant in a dry seedbed unless the land is irrigated.

When the best summer-fallow tillage methods are used, soil moisture is stored and soil erosion by wind is prevented (fig. 1). Blades, sweeps, chisel-harrows, one-way disk plows, chisels, listers, and rod weeders may be used. It is desirable to leave some cover, to roughen the soil surface, or both for the winter and early spring. Weed control on fallow is necessary so that moisture is not depleted.

Because of costs, destruction of residues, and adverse effects on soil structure through compaction, farmers prefer to till the soil as little as possible. If weeds can be controlled with chemicals, it is possible in some instances to plant directly into wheat stubble without seedbed preparation and

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FIGURE 1.—Undercutting wheat stubble for next year's sorghum crop. Plant cover will lessen erosion and help conserve rain and snow. (Courtesy of Kansas Agricultural Experiment Station.)

obtain good stands if the soil is mellow. Minimum tillage methods such as plow-planting, till-planting, and listing are sometimes used when sorghum follows other crops. However, these methods create relatively rough seedbeds and may produce poor stands. As more herbicides are used in farming systems, preplant tillage operations may become less necessary.

PLANTING

Methods

Grain sorghum seed is small. Do not plant it too deep, since it lacks soil-penetrating ability. Cover it immediately and firm the soil to promote moisture absorption, germination, and emergence. A 1-inch planting depth is sufficient if the soil is moist and friable. A 2-inch depth may be necessary when the soil is dry. Newly planted sorghum is vulnerable to a hard rain followed by rapid drying that crusts the soil. When the seedlings have emerged, further crusting causes little damage. Sorghum is planted in beds under irrigated culture, and good emergence is usually assured.

Plant sorghum either in rows wide enough for tractor cultivation or in narrower rows if cultivation is not intended. Row-crop planters for corn, cotton, field beans, and sugarbeets can be used when equipped with the proper seed plates. In the Great Plains where wheat farming is practiced, much grain sorghum is planted with a grain drill that has various feeder holes plugged.

Planters especially designed for grain sorghum also are popular. Many of them are modified listers with furrow openers in the front and covering devices in the rear (fig. 2). They do not plant as deep as the old hard-ground listers nor do they plant as shallow as a grain drill. Nearly all have a small rubber wheel at the rear of the furrow opener that firmly presses the seed into the moist soil and improves stands. They also have planting units that are easily moved on a tool bar to vary the row spacing.

Since traditionally corn was planted in 40- or 42-inch rows (wide enough for a horse to walk), similar planting patterns evolved for sorghum. However, there is a trend toward narrower rows, even on dry land, though extremely narrow rows cannot be cultivated. If weeds are controlled and if the same plant population is maintained, grain sorghum in narrow rows (e.g., 20 inches) will ordinarily outyield that in wide rows (e.g., 40 inches). More efficient use of soil nutrients and water results from a more nearly circular feeding area around each plant. In addition, there is more efficient use of light as the plants are not so crowded in the row. A canopy is

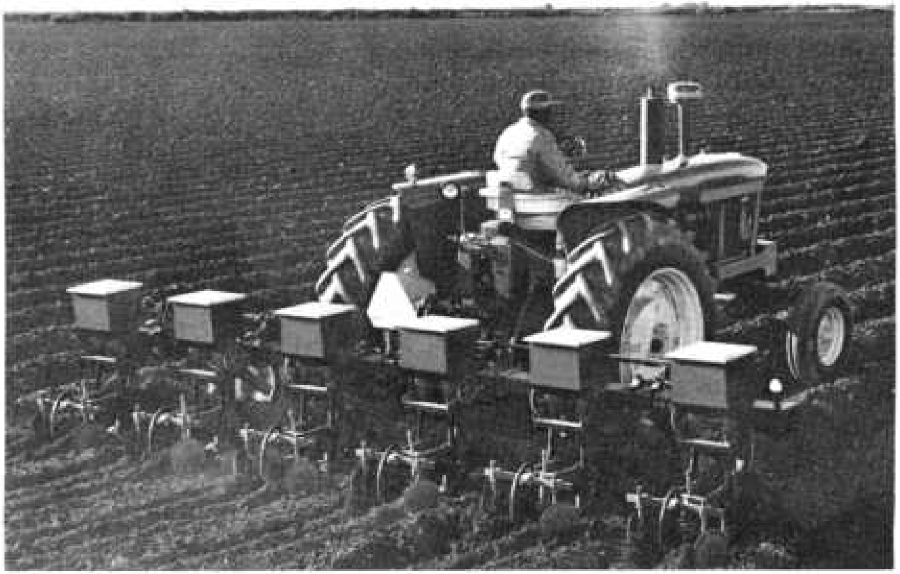

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FIGURE 2.—Conventional planting with loose-ground lister especially designed for sorghum. (Courtesy of Deere & Co.)

soon formed that shades the soil surface, prevents rapid evaporation, and further conserves soil moisture. On sloping land there might be slightly less soil erosion with narrow rows, though they are not a substitute for other conservation practices.

Narrow row widths are used with large plant populations in irrigated and in high rainfall areas. They sometimes interfere with cultivation, but techniques have been devised to allow both cultivation and irrigation down the row. An example is the planting of double rows 12 inches apart with 28 inches to the next row set. This gives the same plant population as 20-inch rows. Other combinations may be used.

Dates

Soil temperature largely determines when grain sorghum should be planted, assuming moisture conditions are adequate. Being semitropical in origin, it should not be planted in the spring until the soil is 65° to 70° F. at the planting depth and there is little chance of subsequent lower temperatures. Since spring days are increasingly longer toward the north, much of the Great Plains from northern Texas to South Dakota, as well as the sorghum-growing area of the western Corn Belt, warms up enough for planting at about the same time. This is from mid-May to early June. Hybrid seed has allowed more successful earlier planting than formerly when varieties were used.

Planting actually begins in mid-February in the coastal bend of Texas and progresses northward until in the high plains of Texas and New Mexico and in the central plains of Kansas and Nebraska planting is mostly in late May and early June. Late plantings of early maturing types can be made in mid-July if necessary in the southern plains. A fall crop sometimes is planted in the Lower Rio Grande Valley, but frost damage is a risk.

Relatively early planting is desirable where chinch bugs are a problem. Much planting is done in late March in north-central and eastern Texas, April and early May in central and eastern Oklahoma, from early to mid-May in eastern Kansas, and mid-May in eastern Nebraska. In these areas the risk of poor stands from early planting is preferable over the risk of insect damage.

In the irrigated areas of southern Arizona and southern California, where high temperatures in midsummer affect growth and pollination, most of the grain sorghum is planted from May to early July. A small amount is planted early, usually in March or April to allow double cropping.

In the South, planting dates range from April to July. The late plantings often follow small-grain harvest and provide two grain crops in one season, but successful midsummer plantings depend on soil moisture and rainfall. The sorghum midge is more likely to damage late plantings in the South as it does in eastern Oklahoma and north-central and eastern Texas.

In the central and northern areas, a common practice is to plant full-season hybrids during the early part of the optimum planting period and progress with earlier maturing types in later plantings. More normal growth is promoted. Stand failures are common with grain sorghum, and replanting often is necessary. If the first planting is made too late in the season and replanting is done, the crop may not mature.

In areas with longer growing seasons, there is interest in "calendarization," which spreads crop growth over the longest possible period and lowers risks. Under this system the earliest hybrids are planted first, the midseason hybrids next, and the full-season hybrids last. If irrigation water is limited, peak requirements are lessened through calendarization.

Rates

Since sorghum seed is small, emergence is difficult under sub-optimum conditions. Poor stands are commonplace and may be due to inferior seed, improper seedbed preparation, inadequate or maladjusted planting equipment, or crusted soil resulting from a heavy rain after planting. Because of experience with poor stands, farmers tend to overplant. The use of high-quality seed and good cultural practices can do much to alleviate the problems associated with obtaining a desirable stand, except for soil crusting. Rotary hoeing a crusted field prior to emergence may help obtain a satisfactory stand, but hoeing at emergence may break off too many seedlings.

Planting rates formerly were expressed in pounds per acre. The recommendations did not give accurate stand expectations because of variation in seed size among varieties. Grain sorghums range from well under 15,000 to over 20,000 seeds per pound. The seed of most hybrids is larger than that of varieties grown 15 years ago except some of the true milos and feteritas.

A practical recommendation for rate of planting is the seed required for a given plant population per acre. Once the desired plant population and the row width are determined, then the planter can be calibrated to drop the required number of seeds per foot of row. Table 3 lists plant populations per acre for the commonly used row widths at two assumed emergence rates. Recommendations formerly were based on an average of 50 percent of the plants producing seedlings. With improved seed technology, one can now expect 75-percent emergence under favorable planting conditions. Using this figure and 20-inch row spacing, a planter calibrated to drop about two seeds per foot of row would produce 39,000 plants per acre. If a lower emergence is expected because of low soil tem-

TABLE 3.—*Plant populations at 2 emergence rates in 3 row widths*

Space between seeds dropped (inches)	Plants per acre at indicated emergence and row widths (inches)					
	100 percent			75 percent		
	10	20	40	10	20	40
	Thousands	*Thousands*	*Thousands*	*Thousands*	*Thousands*	*Thousands*
1	627	314	157	460	235	118
2	314	157	78	235	118	59
3	209	105	52	157	78	39
4	157	78	39	118	59	29
5	125	63	31	94	47	24
6	105	52	26	78	39	20
7	90	45	22	67	34	17
8	78	39	20	59	29	15
9	70	35	17	52	26	13
10	63	31	16	47	24	12
11	57	28	14	43	21	11
12	52	26	13	39	20	9

peratures or other unfavorable conditions, adjustment in the number of seeds dropped per foot can be computed readily from the table.

Some experiment stations recommend planting rates based on square inches per plant. This is merely a means of expressing plant per unit of area. Plants per acre can be computed by the following equation:

$$43{,}560 \text{ sq. ft.} \times \frac{144 \text{ sq. in.}}{\text{square inch per plant}} = \text{plants per acre}$$

Under a given set of field conditions, use approximately the same population regardless of the planting method or row width. A problem of overseeding often arises in grain-drilled sorghum, where the low rates required for dryland sorghum are difficult to attain with this machine. However, some of the newer grain drills for both sorghum and wheat can be geared to plant a small amount of seed. Some grain sorghum hybrids have been developed that have grasslike characters and require a higher planting rate like small grains.

Most of the dryland grain sorghum in the Great Plains is planted to produce stands of between 15,000 and 50,000 plants per acre, with usually 20,000 to 35,000. The lower rates are used in the western areas of low rainfall and the higher rates on the fringes of the Corn Belt. In areas of higher rainfall or where irrigation is practiced, stands may range from 50,000 to 100,000 or more plants.

Under full irrigation, high planting rates are necessary to maximize yields. Ordinarily populations should range between 100,000 and 120,000 per acre. With such stands, narrow rows are necessary to prevent crowding within the row. As a result, much irrigated grain sorghum is planted with a grain drill. High populations require more water and soil nutrients, and the plants compete for sunlight and possibly carbon dioxide.

After the sorghum crop has emerged, field stands should be counted to determine whether replanting is necessary. A sorghum field often appears to have a poorer emerging stand than it actually has, especially when a low planting rate was used. Failure to make counts can result in unnecessary replanting.

Sorghum partially compensates for wide distances between plants in the row by tillering. This results in more heads and helps adjust for yield differences provided the initial stand is not too thin. Tillering is most pronounced on heavy or clayey soils during favorable seasons and provides some latitude in planting rates. However, planting rates should be geared to the soil capabilities, soil-moisture supplies at planting, and expected rainfall or planned irrigations.

WEED CONTROL

Sorghum, a warm-season crop, is planted and grown under conditions favoring weed germination and growth. Sorghum seedlings are relatively small and weak, grow slowly under cool or adverse conditions, and do not compete with weeds. Therefore, weedy stands must be remedied either by replanting the sorghum crop or by controlling the infestation.

Cultivation

Preplant tillage operations destroy many weeds. They include cultivation early in the fallow period as well as seedbed tillage near planting. Usually weed growth determines when the operations are performed. Tillage is minimum during periods of little or no weed growth.

Planting at the proper time in a weed-free seedbed promotes rapid emergence of the sorghum and gives it an initial advantage over early weed growth. However, weeds appear sooner or later and are particularly troublesome following a rain, which promotes germination and growth. Several mechanical control measures are available.

If the sorghum crop has emerged, is well rooted, and is several inches high and if the weeds are small and shallow rooted, rotary hoeing may be successsful. It destroys weeds in the row as well as between the rows, but it can damage the sorghum plants. If the soil has crusted before crop emergence, the rotary hoe can benefit stand establishment. Sometimes a spiketooth harrow is used in lieu of a rotary hoe, but it is likely to damage young sorghum plants.

Rotary hoeing is the only means of cultivating drilled sorghum where the rows are too narrow to use other cultivators. It is not adapted to furrowed plantings, though special rotary attachments are available for cultivating listed crops.

Row-crop cultivators are most commonly used for sorghum planted in conventional rows (fig. 3). Cultivation may also be preceded by rotary hoeing. Tractor cultivators originally were designed for conventional 40- or 42-inch rows, but equipment is now available for 30-inch rows, following the trend to narrow-row corn culture, and is readily adapted to sorghum. If row widths less than 30 inches are used, special equipment such as sugarbeet cultivators may be necessary. Rows narrower than those used for sugarbeets do not allow deployment of most farm tractors through the field.

Most sorghum is cultivated one to three times depending on the reoccurrence of weed problems. Cultivate only as deep as necessary to destroy weeds. Avoid excessive root pruning to prevent

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FIGURE 3.—First cultivation with row-crop cultivator throwing dirt away from young plants; second cultivation will throw dirt in and mound soil around crowns. (Courtesy of Deere & Co.)

permanent plant damage. Only rarely is it necessary to cultivate sorghum to improve soil tilth and to aid water intake during the growing season. Good sorghum crops have been grown without any mechanical cultivation after planting and soil structure has not been affected, even on rather heavy silty clay loams.

Flame cultivation is sometimes used for cotton and may be adapted to sorghum. The sorghum plants should be at least 12 inches tall, and the flame should be directed basally in the row. Generally only the tops of weeds are killed, but the bottom leaves of sorghum are likely to be damaged. Experimentation in a few rows is advisable before flaming the entire field.

Chemical Methods

Chemical control of weeds is a part of the growing technology of sorghum culture. When used correctly chemicals are a boon to sorghum production, but when used haphazardly they may be a disappointment. For sorghum that is drilled or planted in rows too narrow for mechanical cultivation, chemicals may be the only possible means of weed control. The successful use of herbicides depends on accurate calibration of the sprayer and on closely following the label instructions with respect to rate and time of application for specific soil types, climatic conditions, types of weeds to be killed, their stage of growth, and the stage of growth of the sorghum itself.

Herbicides are applied before the sorghum is planted (preplant), before it emerges (preemergence), or after it comes up (postemergence). Rain after application increases effectiveness of preemergence treatments, but a heavy rain may concentrate the chemical in the seed row, increase crop injury, and decrease weed control. Planting seed 1 inch deep or more increases the safety margin. If no rain occurs after chemical application, a shallow mechanical cultivation, if possible, may aid in incorporation.

Several chemical herbicides are registered for weed control in sorghum. Discussions here are based on the amount of actual chemical or active ingredient. Two of the most widely used herbicides are the related triazine compounds, atrazine and propazine. Atrazine is used as either a preemergence or a postemergence spray depending on the area and other conditions. The preemergence rate is 1 to 2 pounds per acre and ordinarily controls small grassy and broadleaf annual weeds. However, crop injury is a risk and limits the use of atrazine as a preemergence treatment. Problems are likely to arise when atrazine is applied on coarse-textured (sandy) soil or other soils low in organic matter.

Atrazine is often successfully used as a postemergence application. For best results the sorghum should be at least in the two- to three-leaf stage and the weeds less than an inch tall. The chemical is particularly effective against broadleaf weeds [illegible]g weed and kochia and it [illegible]control weed grasses if they are extremely small. Higher rates of atrazine are used for postemergence (2 to 3 pounds per acre) than for preemergence treatments.

Propazine is less likely to injure sorghum than atrazine, but it may not control weed grasses as well. It is used as a preemergence application at 1 to 2½ pounds per acre. As with atrazine, injury to the crop is likely if propazine is applied on sandy soils or other soils low in organic matter. Both atrazine and propazine can be banded or sprayed broadcast. Only the latter is practical if the crop is in rows too narrow for cultivation.

In research, highly refined mineral oil has been evaluated as an additive to replace part of the atrazine in postemergence treatments. The addition of oil reduces the amount of atrazine required per acre, slightly increases the effectiveness, and decreases the cost of the treatment. The decrease in amount of atrazine required probably lessens the residual toxicity with respect to subsequent crops. Injury to the treated sorghum crop, however, has been common, and the relative advantages of the combination treatment are doubtful.

Norea and propachlor also are registered for control of weeds in sorghum. Norea is applied preemergence at about 2 pounds per acre. Sometimes reduced rates of norea and atrazine or propazine are mixed together for more complete weed control where both broadleaf weeds and weed grasses are present. Propachlor is used as a preemergence treatment at 4 to 5 pounds per acre.

Continued research will probably result in the development and use of other herbicides, either alone or in combination. Obviously they will have to be very selective in their action. Controlling johnsongrass and wild cane (shattercane) in sorghum fields by chemical means is a special challenge, for these pests are themselves sorghum. Cultural and rotational approaches to their control are the most practical.

Formerly 2,4–D was the only herbicide available for weed control in sorghum. Although other herbicides are now available, 2,4–D is widely used in wet seasons when other chemical and mechanical weed-control methods are impossible or fail. It controls only broadleaf weeds at rates used in grain sorghum. The ester formulations are normally used at one-fourth to one-half pound per acre and the amine formulations at one-third to two-thirds pound per acre. Though 2,4–D may injure sorghum at any stage of growth, it is less likely to do so when the plants are 4 to 10 inches tall. A basally directed spray will keep more chemical out of the leaf whorls and reduce danger to the crop when it is over 10 inches tall, but this may not be possible if the weeds are tall.

Root development is sometimes inhibited in sorghum by 2,4–D, and a normal-appearing crop may lodge later in the season. Other symptoms of damage are brittle stalks, stunting, leaf curling, height variability, head sterility, and yield reduction.

During wet seasons when ground application of chemicals is not possible, considerable acreages of sorghum are aerially sprayed for weed control. Care must be exercised to avoid damage to other crops in nearby or adjoining fields, windbreaks, gardens, and shade trees in or near farmsteads. Application is best made on a calm day. Even with ground application, the same precautions are advisable. Some chemicals are volatile, and fumes can drift for several miles from the field being sprayed. Mist (fine droplets) from chemicals that are not very volatile can also drift for several miles if applied when the wind velocity exceeds 2 or 3 miles per hour.

COMMON AND CHEMICAL NAMES OF HERBICIDES

Common name	*Chemical name*
Atrazine	2-chloro-4-(ethylamino)-6-(isopropylamino)-*s*-triazine
Norea	3-(hexahydro-4, 7-methanoindan-5-yl)-1, 1-dimethylurea
Propachlor	2-chloro-*N*-isopropylacetanilide
Propazine	2-chloro-4, 6-bis (isopropylamino)-*s*-triazine
2,4-D	2,4-dichlorophenoxyacetic acid

FERTILIZERS

Grain sorghum is a soil-depleting crop. It feeds heavily on nutrients, and when it follows wheat, cotton, or grain sorghum, the soil often is left low in fertility. However, with adequate fertilization, water, and proper management, most soils can sustain high crop production. Experiments in Texas have shown that the grain in a 100-bushel-per-acre sorghum crop removes about 100 pounds of nitrogen (N), 14 pounds of phosphorus (P), and 14 pounds of potassium (K). Soil amendments can be based on these data plus other conditions peculiar to the fields.

Nitrogen is most often the limiting element in grain sorghum production, and the need is related to soil type, moisture considerations, and yield level. On dryland farms in the western Great Plains, where the soils are inherently fertile and rainfall is low, response to nitrogen is generally limited to the wetter years. On the other hand, good response can be expected almost every season in the irrigated and higher rainfall areas.

Rates of nitrogen vary considerably, but 20 to 40 pounds per acre are commonly applied to dryland fields and 40 to 60 pounds to the better soils in areas with higher yield potential. If the nitrogen is not used because of drought, it is carried as a reserve for the succeeding crop, since soil leaching is minor under these conditions. The need for nitrogen is greater on sandy soils low in organic matter than on heavy soils. Farmers have been using increasingly greater amounts of nitrogen on irrigated sorghum. Less than 100 pounds per acre have been used, but from 100 to 150 pounds are common. Though extremely high rates of nitrogen (200 to 300 pounds per acre) have been used in the Great Plains, the additional yield increases may be small and uneconomical. In the South, extremely high fertilizer applications are necessary, since many of the soils are depleted from heavy cropping and by excessive leaching from high rainfall.

Nitrogen is used at various times but most often as a preplant application, at planting, and as a side dressing at cultivation. Since this last is not always possible with narrow-row culture, many farmers use about one-half at preplanting and one-half at planting. In areas with low winter temperatures and light precipitation, the application can be made anytime in the late fall or thereafter.

Some farmers use a little nitrogen as a starter fertilizer, but more than 8 or 10 pounds per acre with the seed will be detrimental to germination. It is better to place the fertilizer in a band a little to the side of the newly planted seed.

Some apply nitrogen in irrigation water to the growing crop.

This technique requires careful metering of the fertilizer and proper distribution of water in the fields. Corrosion of the irrigation system is a risk.

Various nitrogenous carriers are available, and each is equally effective on an actual nitrogen basis. Cost per pound of nitrogen availability of the product and ease of application are deciding factors as to which carrier to use. Anhydrous ammonia is probably the most common preplant carrier, though liquid nitrogen (an ammonium nitrate urea aqueous solution) is widely used. Prepared fertilizers of different N–P–K ratios or ammonium nitrate alone are commonly used at planting.

Phosphorus and potassium requirements for grain sorghum are not so great as for nitrogen, and the soil reserves are generally more adequate. However, continued high crop production may make phosphorus application advisable, and under certain conditions potassium may be deficient. Soil tests, knowledge of the soil type and its characteristics, and experience will determine whether phosphorus or potassium amendments are necessary. Specific recommendations can be obtained from the county agent or the State agricultural experiment station.

Calcium deficiencies may occur in the Corn Belt and in the South, but liming is ordinarily a routine fertility practice in these areas. In most of the sorghum-growing areas the soils are calcareous, and problems sometimes arise from high pH conditions. Iron deficiencies often occur in young plants and are more common on the lighter or sandier soils. The problem is largely lack of availability to the plant rather than a shortage of the element in the soil.

Yellowing due to iron deficiency is unlike yellowing from lack of nitrogen. The former shows up in young plants, whereas the latter does not appear until later in the season. Plants showing iron deficiency are more likely to be uniformly chlorotic, whereas nitrogen-deficient plants exhibit symptoms on the older leaves. Sorghum often outgrows the iron deficiency as the plants develop a more extensive root-feeding area. The most practical and most economical remedy for iron deficiency is to use foliar sprays of organic iron forms, called chelates. They are more conveniently used in sprays than such inorganic forms as iron sulfate, whereas soil applications of iron compounds require prohibitive amounts.

Zinc deficiencies often occur on irrigated land that required extensive land leveling. Chelated forms of zinc are available for correcting the problem. Experience has shown that zinc deficiencies tend to be alleviated after several years of cropping and returning plant residues to the ground.

Other plant nutritional problems may occur in specific areas and may need special diagnosis. Local or State agricultural advisers should be consulted.

Though commercial fertilizers are generally used for sorghum, there may be special situations where manure is available as from cattle feedlots or poultry-laying houses. Plant wastes from canning or food-processing plants and sewage sludge are other examples of organic fertilizers. If these sources can be obtained and applied economically, they may be utilized. Always incorporate them into the soil through tillage to promote decay and to prevent nitrogen losses to the atmosphere.

IRRIGATION[2]

More than 25 percent of the grain sorghum acreage in the United States is irrigated, including most of the California, Arizona, and New Mexico crop. Though grain sorghum is drought tolerant, it responds to favorable moisture conditions. Yields of 6,000 to 8,000 or more pounds per acre often result from irrigated plantings when fertility and plant populations are optimum.

Limited water supplies are most efficiently used through preplanting irrigations in the off-season, when work can be spread over a longer interval than is possible during the growing season. The best soils are medium or medium-fine textured and have deep profiles for high water absorption. Soil wet to 6 feet preplant will often produce a satisfactory crop with only one additional irrigation, usually at booting or heading time. Sorghum roots draw moisture reserves from great depths if required, as demonstrated in Kansas experiments, where the crop utilized water from a 90-inch depth when the field was wet to capacity to 7 feet at planting and no additional water (except 5 inches of rainfall) was applied during the growing season.

Under full irrigation most growers water two to four times and depend on rainfall during the growing season to supply about half the requirements. But timeliness of irrigation is important as plants should never show drought stress. If the soil moisture falls below 25 percent in the upper 2 feet, yields likely will be adversely affected. Although the period of heaviest water use is at booting and heading, irrigation may be necessary 2 or 3 weeks after planting if no rain falls and the weather is hot.

When fertilizers are applied and no rain occurs, it will be necessary to irrigate early so that the nutrients will be available to the young growing plants. Soils low in fertility utilize water more efficiently when fertilizers are used. It is also more economical to irrigate with high rates (e.g., 4 inches at a time) if the soil is not

[2] See also U.S. Dept. Agr. Leaflet 511, "Irrigating Grain Sorghums."

sandy than to irrigate oftener with lower rates.

Do not apply water once the grain is in the dough stage. Excessive soil moisture at this time encourages tillering and head branching and prevents the plants from drying out for harvest. However, lodging can be a problem if soil-moisture supplies are completely depleted before the crop is mature.

Irrigation of most grain sorghum is with graded furrows, but level furrows, level borders, graded borders, and sprinklers are sometimes used. Sprinklers are adapted to rolling land and to sandy soil. Gated pipes are popular in some areas for furrow irrigation because they reduce ditching, lessen head-ditch erosion, and control the water better.

HARVESTING, DRYING, AND STORING

Nearly all grain sorghum is harvested standing with a combine (fig. 4). In the central and northern Great Plains, the crop usually is harvested after frost. In the other major production areas where the growing seasons are longer, combining is done when the grain is ripe.

Sorghum grain readily threshes free from the head when the seed moisture content is 20 to 25 percent. The seed is physiologically mature at even a higher level. Though ripening is largely a process of lowering moisture content, grain must reach a safe, low level for harvest unless artificial drying is used; otherwise it might spoil in the bin. A maximum moisture content of 13 percent in the Great Plains and Southwest and 1 or 2 percent less in the Corn Belt and South is desirable.

Hybrids with head stems that dry out after the grain matures are popular since they can be harvested earlier in the fall. Harvesting hybrids with green heads must wait generally until a light frost has killed the top of the plant. Usually the grain is sufficiently low in moisture a week after such a frost.

Since hybrids differ in threshability, concaves can be set and cylinder speeds adjusted so that any hybrid can be satisfactorily threshed. Threshing should be as clean as possible since bits of stems, leaves, and head branches carry much moisture.

Ordinarily grain sorghum does not grow excessively tall under dryland conditions, but it can attain great height under irrigation and in wet seasons. Generally the heads are better exerted when the plants are tall. In thick plantings grain sorghum also tends to grow taller and have smaller heads. If lodging is a problem, most of the crop can be salvaged by installing pickup attachments on the combine.

Wet grain, either from the combine or in the bin after storage, is best handled by air drying.

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FIGURE 4.—Combining a dryland field after frost. (Courtesy of Deere & Co.)

Unheated air can be used if the grain is not too damp or if the humidity is not too high. Damp grain and high humidity require higher air volumes, and drying operations may have to be limited to the drier parts of the day. Hot-air driers are more popular in the sorghum-growing areas of higher rainfall where harvest problems are common. They allow combining before the onset of inclement weather and before lodging becomes serious.

Temperatures must be judiciously considered with hot-air drying. Grain heated over 200° F. may lose some of its feed value through oxidation of carbohydrates. Grain that is to be industrially milled should not be heated over 140° as the starch may be modified. A crop harvested for seed should not be heated over 110° or germination may be reduced.

Before storing sorghum grain thoroughly clean the bins. Sweep floors and walls and then spray with an effective insecticide that is safe to apply and safe for livestock if the grain is to be fed. Remove potential insect-breeding grounds in and around the bins, such as feed and seed residues and dirty grain sacks.

Insect infestations later may be controlled through fumigation. Take precautions against inhaling poisonous fumes and safeguard against fire as some fumigants are highly volatile. Generally grain sorghum requires higher rates of fumigants than wheat because the kernels are packed together more closely. It is for this reason that heating in the bin is more of a problem.

Clumping of the grain and a musty smell indicate excessively high moisture and spoilage. To prevent these problems, either use additional air drying or move the grain from one bin to another. Moving several times may be necessary since lowering grain temperature is the primary effect rather than lowering moisture. Generally spoilage is less serious during cold weather. Much grain is stored at temperatures too high for continued safe storage, but problems seldom occur if it is used for feed by spring.

UTILIZATION

Feed Value

Grain sorghum is similar chemically to corn, but generally it is a little higher in protein. However, protein can vary considerably depending on the conditions under which the crop was grown. High yields tend to lower protein, whereas nitrogen fertilization tends to increase it. Immature grain, in which carbohydrate deposition is incomplete, has more protein than mature grain. Like corn, grain sorghum is particularly deficient in lysine, and also when the total protein is increased, the most essential amino acids make up a relatively lower percentage of the total.

The fatty acids in sorghum grain and corn are almost identical, though corn tends to have a little higher total fat content. Mineral composition of the two crops differs only slightly.

A major difference is in vitamins. Ordinary grain sorghum, even with colored seedcoats, is like white corn in that it is practically devoid of carotenoid pigments and vitamin A precursors. The best yellow endosperm varieties from Africa have about half as much carotenoid and xanthophyll pigments as yellow corn, and adapted American-derived breeding stocks often have less. Yellow pigments dissipate more readily from sorghum grain in the head than from corn in the shuck because of exposure to the elements. Breeders are attempting to develop better grain sorghums with higher vitamin A content, but it is necessary to have the character in both parents of a hybrid. Grain sorghum is higher in niacin, a B vitamin, than corn, though this vitamin ordinarily is not lacking in livestock rations.

Feeding experiments have shown that grain sorghum and corn are, in general, about equal in feed value. Best results have come from feeding sorghum to laying hens and to broilers. Also, grain sorghum has or nearly equaled corn in rations for milk cows and for fattening lambs. It has tended to be slightly less valuable than corn for fattening both beef and swine, though in some experiments they have been found to be the same. The slightly lower value for sorghum in feeding beef and swine may be due to differences in fat content, amino acid balance, and other unrecognized chemical or physical differences between the two grains. Meat flavor, texture, and appearance of animals fed sorghum grain are equal to those fed corn.

Feed differences are usually reflected, sometimes unjustly, in a market-price differential between the crops. When grain sorghum is priced 95 percent or less than corn per hundredweight, it is probably the better buy. If feed grains are home grown, the dollar return per acre in most of the sorghum-growing area will be greater for sorghum than for corn because of higher yields.

Sorghum grain is highly palatable to livestock, and intake seldom limits livestock gains. Certain varieties and hybrids, however, are less palatable, and the bitterness is often associated with tannins and phenolic compounds. Some of these sorghum types were developed to deter birds from feeding in the field. External conditions, such as molds on weathered grain, can also affect palatability. Mycotoxins produced by molds on grain in the head or on grain in the bin may affect animal health.

Most sorghum grain is processed (cracked, ground, or rolled) before feeding, though it was common formerly to feed whole sorghum grain to swine and sheep. Sheep still utilize unground grain effectively, but whole heads should be ground if fed to sheep. In addition, much of the sorghum grain fed to cattle is modified further by special processing, such as steam rolling or flaking. Feed efficiency allegedly is increased. In large commercial feedlots the use of more refined processing equipment apparently is economical.

High-moisture sorghum grain (e.g., about 25 percent) may be ensiled and later fed to cattle. The grain keeps well if it is not exposed to the air. Both upright and trench silos have been used successfully. This method of utilization allows earlier harvest and eliminates problems associated with bin storage of sorghum grain. Also, high-energy silage can be made from grain sorghum heads alone or from the entire plant. A crop often can be salvaged this way when it will not mature for grain.

Pasturing cattle or sheep on combined sorghum stubble is a common practice (fig. 5). Both roughage and dropped heads are utilized. Some sorghums, particularly those with juicy stems and leaves, are preferred for postharvest grazing. These same types, however, are slowest to dry out for combining unless a frost occurs. The stalks from a low-yielding grain crop tend to have more sugars than from a high-yielding crop.

Stubble with secondary growth should be pastured carefully, if at all, because of the danger of prussic acid (HCN) poisoning. The

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FIGURE 5.—Cattle grazing on grain sorghum stubble after harvest. (Courtesy of Kansas Agricultural Experiment Station.)

problem tends to be more serious in the central and northern parts of the sorghum region.

Industrial Use

Most of the grain sorghum grown in the United States is fed to livestock, but about 10 million bushels are milled annually for starch or flour or for producing industrial alcohol. Both wet and dry milling are employed, utilizing both waxy (glutinous) and ordinary grain. Starch flour is used principally in building materials, primarily wallboard. Other uses are for sizings, adhesives, oil-well drilling muds, and food products. Sorghum starch is converted to dextrose and is used in the fruit-canning, baking, and confection industries. Important milling byproducts are livestock feed and oil.

During World War II grain sorghum was a prime source of industrial alcohol, and waxy sorghum starch was substituted for tapioca. Research is developing new industrial uses for grain sorghum as well as new grain sorghums for these uses.

DISEASES

Diseases attacking grain sorghum can be classified as seed rots and seedling blights, foliar or leaf diseases, inflorescence or head diseases, and root and stalk rots. They are caused by fungi, bacteria, and viruses, or they may be physiological in nature.

Many diseases of sorghum cannot be adequately or economically controlled by chemical means. Resistance is known for several diseases. Using resistant varieties or hybrids when available will help to minimize crop damage.

Seed Rots and Seedling Blights

Seed rots and seedling blights are most severe when the soil is wet and cold following planting. Under such conditions the seed fails to germinate because it is attacked by various seedborne and soil-inhabiting fungi that soon rot it. To control these rots most effectively, plant sound seed free of cracks, treat it with a fungicide such as captan or thiram, and plant after the soil approaches 70° F.

Foliar or Leaf Diseases

Leaf diseases are generally destructive in areas with high rainfall and high humidity. Bacterial stripe, bacterial streak, and bacterial spot often are present but usually do not cause serious losses. During warm, moist seasons these diseases may spread rapidly from the lower to the upper leaves until they destroy much of the leaf surface.

The fungus leaf diseases include anthracnose, leaf blight, zonate leaf spot, gray leaf spot, rough spot, target spot, sooty stripe, rust, and downy mildew. Other than downy mildew, these diseases seldom reach economic importance except in the South.

Downy mildew only recently became important and has been reported in several major sorghum-growing States. Early infected plants may become stunted and chlorotic, characterized by yellow-white streaked whorl leaves. A midseason, nonsystemic condition can occur in which "down" appears on the lower leaves and terminates in leaf blighting. A late-season systemic symptom, the disintegration of leaf tissue, gives a ragged appearance. Resistant varieties are the best means of control. Another downy mildew, called crazy top, is not so serious and occurs in low, wet areas. The plants are stunted and chlorotic, with thickened, twisted leaves. If heads are produced, they are proliferated.

Maize dwarf mosaic (MDM) is the most serious virus disease of sorghum, and it too only recently became prominent. It is a mutant of the sugarcane mosaic virus and is transmitted by aphids. Early infection produces stunting and mottling. Older plants often have a red-leaf symptom characterized by striping or streaking with deep pigmentation of necrotic areas. Badly infected plants may fail to head or produce abnormal heads with sterility. As with downy mildew, plant resistance is the best control for MDM. Destruction of johnsongrass and other host plants also is helpful.

Inflorescence or Head Diseases

Smuts are the most common diseases infecting the floral parts of grain sorghum. Head smut is the most serious and attacks the heads, usually destroying them and leaving an open mass of spores. Occasionally the head of an infected plant may be sterile, and smut galls appear later on tiller heads or head side branches. Other heads may show a proliferation of floral parts. Since the disease is soilborne where it infects the young plants, seed treatment is of little help. However, good resistance exists in certain varieties and hybrids.

Covered kernel smut and loose kernel smut are not so serious as formerly when grain sorghum was planted without fungicide treatment. The diseases are similar except the galls are mostly covered in the former and largely broken in the latter. The three sorghum smuts are not poisonous to livestock, and grain that has been contaminated with spores can be fed without harmful effects.

A small-seed condition, whereby the panicle may be partially sterile or may have variable patterns of normal and undeveloped seeds, has occurred in many high-production fields in recent years. The cause is not known except the disorder seems to be associated with cool, cloudy, moist weather following flowering.

Root and Stalk Rots

The most important root and stalk diseases of grain sorghum are periconia root rot (milo disease), anthracnose, charcoal rot, fusarium and rhizoctonia stalk rot, and weak neck.

Periconia root rot attacks milo, darso, and their derivatives but not other groups of grain sorghum. If susceptible seedlings do not die soon after emergence, they often have the appearance of drought damage. Resistant mutants were found in milo, and now all commercial hybrids are resistant to the disease.

Anthracnose stalk rot, also called red rot, is caused by the same fungus that causes anthracnose leaf blight. Culms or stalks become invaded; the tissue becomes diseased, rots, and finally dries; lodging or reduced grain and stalk quality often results. Good cultural practices and crop sanitation help confine the disease in the absence of plant immunity.

Charcoal rot attacks the stalk as the plant nears maturity. The pith dries and disintegrates so that the stalk is weakened and finally breaks at the base. A few varieties are partly resistant to charcoal rot, and this offers the principal source of control. This disease is most serious when the plants suffer from a shortage of soil moisture.

Fusarium stalk rot produces symptoms similar to those of charcoal rot, but the spores in the rotted stalks are white instead of black. The fungus apparently enters the plant through openings made by insects and mechanical injuries. Fusarium rot is commonly found as a secondary infection in diseased plants.

Rhizoctonia stalk rot differs from charcoal rot in that the vascular fibers appear as light streaks in a reddish discolored pith. The fruiting bodies are brown instead of black and appear on the outside of the stalk instead of inside.

Weak neck is a nonparasitic disease. Combine-grain varieties with heavy heads but a weak head stem that dries when the grain ripens often develop a rot at the base of the head stem within the boot where moisture accumulates. Bacteria and fungi cause the rotting. The stem is weakened so that the heads break during high winds.

CAUSAL ORGANISMS OF SORGHUM DISEASES

Common name	*Causal organism*
Anthracnose	*Colletotrichum graminicola* (Ces). G. W. Wils.
Bacterial spot	*Pseudomonas syringae* v. Hall
Bacterial streak	*Xanthomonas holcicola* (Elliott) Starr & Burkh.
Bacterial stripe	*Pseudomonas andropogoni* (E. F. Sm.) Stapp
Charcoal rot	*Macrophomina phaseoli* (Maubl.) Ashby
Covered kernel smut	*Sphacelotheca sorghi* (Lk.) Clint.
Crazy top	*Sclerophthora macrospora* (Sacc.) Thrim., Shaw, & Naras
Downy mildew	*Sclerospora sorghi* Weston & Uppal
Fusarium stalk rot	*Fusarium moniliforme* Sheldon
Gray leaf spot	*Cercospora sorghi* Ell. & Ev.
Head smut	*Sphacelotheca reiliana* (Kuehn) Clint.
Leaf blight	*Helminthosporium turcicum* Pass.
Loose kernel smut	*Sphacelotheca cruenta* (Kuehn) Potter
Maize dwarf mosaic	aphid-transmitted virus
Milo disease	*Periconia circinata* (Mangin) Sacc.
Rhizoctonia stalk rot	*Rhizoctonia solani* Kuehn
Rough spot	*Ascochyta sorghina* Sacc.
Rust	*Puccinia purpurea* Cke.
Sooty stripe	*Ramulispora sorghi* (Ell. & Ev.) L. S. Olive & Lefebvre
Target spot	*Helminthosporium sorghicola* Lefebvre & Sherwin
Zonate leaf spot	*Gloeocercospora sorghi* D. Bain & Edg

INSECTS[3]

Several insect species attack grain sorghum. Some of the most important economically in the United States include the following species:

Grasshoppers

Grasshoppers frequently do considerable damage to grain sorghum. If very abundant, they strip the leaves from the plant and feed on the heads.

Fields can be protected from grasshopper injury by destroying young nymphs in adjacent field margins, ditchbanks, or wastelands with an insecticide before they move into grain sorghum.

Proper tillage in the fall and spring, if in conformance with good soil conservation practices, will destroy many grasshopper eggs and reduce subsequent infestations in the vicinity.

Corn Earworm

The corn earworm is found throughout the grain sorghum area. The larvae feed in the leaf whorl and on the developing head. Varieties with open heads give some protection from this insect.

Sorghum Webworm

The sorghum webworm is often abundant in the eastern part of the grain sorghum area. When abundant this insect may destroy the developing grain. Destruction of plant residues and early planting are cultural aids.

Corn Leaf Aphid

The corn leaf aphid is sometimes common on grain sorghum throughout the central and southern Great Plains. It is usually found in the central whorl or on the panicle after emergence. Occasionally it is so abundant that it prevents the formation of grain. No cultural control of the aphid is effective.

Sorghum Midge

The sorghum midge sometimes prevents the profitable production of grain sorghum in the more humid areas. The adults lay their eggs in the flowers, and the larvae suck the juices from the developing seed.

Locate grain sorghum fields as far as possible from outside sources of infestation, such as johnsongrass or earlier planted grain sorghum. To reduce possible damage, planting should be timed so that sorghum will bloom when the adult insects are not abundant in the fields.

Chinch Bug

The chinch bug in some years is a serious pest of grain sorghum in the eastern part of the sorghum-growing region. The first-generation eggs are laid in fields of small grain, where the young nymphs feed. As the grain ripens the older nymphs and adults mi-

[3] Prepared by Entomology Research Division.

grate to nearby corn or grain sorghum. They suck juice from the plants and thus weaken and sometimes kill them. Chinch bug injury can be reduced by planting resistant varieties early and as far as possible from infested small grains.

Other Insect Pests

Several other insects sometimes injure grain sorghum. Among them are the southwestern corn borer, lesser cornstalk borer, European corn borer, flea beetle, stinkbug, fall armyworm, white grub, greenbug, and various species of ants.

The greenbug became a serious pest in most of the sorghum-growing area in 1968. Infestations first occur on the lower leaves and then move upward on the plant. Small plants are completely destroyed and large plants lose their lower leaves. A population of 30,000 aphids per plant is not unusual. This aphid feeds and reproduces during hot weather at temperatures as high as 110° F. No cultural control is effective, but several insecticides are satisfactory if applied in time.

COMMON AND SCIENTIFIC NAMES OF IMPORTANT INSECTS THAT ATTACK SORGHUM

Common name	*Scientific name*
Chinch bug	*Blissus leucopterus* (Say)
Corn earworm	*Heliothis zea* (Boddie)
Corn leaf aphid	*Rhopalosiphum maidis* (Fitch)
European corn borer	*Ostrinia nubilalis* (Hübner)
Fall armyworm	*Spodoptera frugiperda* (J. E. Smith)
Greenbug	*Schizaphis graminum* (Rondani)
Lesser cornstalk borer	*Elasmopalpus lignosellus* (Zeller)
Sorghum midge	*Contarinia sorghicola* (Coquillett)
Sorghum webworm	*Celama sorghiella* (Riley)
Southwestern corn borer	*Diatraea grandiosella* Dyar

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